A New Distortion Measure for Video Coding Blocking Artifacts

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ABSTRACT

A new generalized Block-edge Impairment Metric (BIM) is presented in this paper as a quantitative distortion measure for the blocking artifacts in digital video, as well as digital image coding. This distortion measure only uses information contained in the reconstructed images and it is found to be consistent with subjective evaluations.

1. INTRODUCTION

Video sequences coded by either hardware or software compliant with the existing international video compression and coding standards [1] manifest various reconstruction artifacts, some of which are well known such as blocking (including edge and DCT basis image artifacts), ringing, mosquito effects, and others less well known such as stationary area granular noise and chrominance mismatch[2]. Coding distortion and error propagation become significant when the algorithm is used to code video images under a certain low bit rate or for high quality video images such as broadcast TV and HDTV[3]. To provide users with quality video services, causes of these artifacts and their effects on viewing quality need to be understood and objective quality metrics, which are preferably correlated well to subjective measures, are required to evaluate various video codec products, enhancements and new algorithms. At present, the procedures for subjective assessment of video picture quality have been standardized[4], and effective and commonly acceptable objective quality metrics, however, remain to be seen. This lacking of effective quantitative measures have not only frustrated researchers for more than two decades[5] but also made realistic evaluation or benchmarking of various products based on the international video coding standards very difficult if not all impossible. The ineffectiveness of the traditional quantitative measures, such as the Mean Squared Error (MSE), the Signal-to-Noise Ratio (SNR) etc.[1], in quantifying the visibility of reconstruction artifacts is nothing but well known as they do not necessarily reflect our visual perception of the coding distortions or artifacts[6].

In [7], we have shown that the blocking effects and its propagation through reconstructed video sequences are the most significant of all coding artifacts within a range of bit rates anywhere from a few hundred kilobits per second (H.261[8]) to as high as 10 to 12 Megabits per second (MPEG-2[9]). It is also a source to a few other types of reconstruction artifacts. In a most recent paper[10], Karunasekera and Kingsbury introduced a new distortion measure for blocking (edge) artifacts in compressed images based on human visual sensitivity which correlated very well with subjective evaluation results. This quantitative distortion measure requires both the original and the reconstructed images to form the error image as the input to the visual model, as most of the other existing quantitative distortion measures[11,12]. In the absence of the original images, the above distortion measure cannot be used to evaluate the coding artifacts, such as blocking. In [7], an impairment metric for block-edge artifacts was introduced, based on the formulation of constraint sets used in the post-filtering of reconstructed video images using Projections Onto Convex Sets (POCS) algorithms[13]. This metric only needs the reconstructed image as the input and achieves results consistent with subjective evaluations. This metric was modified in [14] to accommodate the effect of illuminance level on the visibility of the "blocking" distortion, i.e. to take into account the illuminance masking effects in extreme bright as well as extreme dark areas in the reconstructed image.

In this paper, a more general formulation of the Block-edge Impairment Metric (BIM)[14] is presented in Section 2, parameters of which can be adjusted to correspond with the visibility of noise modelled in [15]. Section 3 will present some experimental results using

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this generalized BIM as a distortion measure compared with the Peak Signal-to-Noise Ratio (PSNR) values.

2. A GENERALIZED BLOCK-EDGE IMPAIRMENT METRIC

In our previous investigation of enhancement methods for video coding using projections onto convex sets (POCS) algorithms, we used the metric introduced by Yang et al[13] to form the constraint sets in order to minimize the blocking artifacts in the encoder, producing satisfactory results[16]. This metric was used directly as an objective measure for block-edge artifacts in [7] with a straightforward normalization operation. In this section, the above metric is further modified to accommodate brightness masking effects in both very dark and bright areas of reconstructed images.

Given an image $\mathbf{f} = \{\mathbf{f}_{c1}\mathbf{f}_{c2}\ldots\mathbf{f}_{cN}\}$, where $\mathbf{f}_{ci}$ is the ith column of the image array and N is the width of the image, we define the interpixel difference between each of the horizontal block boundaries by

$$D_c\mathbf{f} = \begin{bmatrix} \mathbf{f}_{c8} - \mathbf{f}_{c9} \\ \mathbf{f}_{c16} - \mathbf{f}_{c17} \\ \vdots \\ \mathbf{f}_{c(N-8)} - \mathbf{f}_{c(N-7)} \end{bmatrix}. \tag{1}$$

A metric can be defined to measure the horizontal blockiness by

$$M_h = \| WD_c\mathbf{f} \| = [\sum_{i=1}^{N/8-1} \| \mathbf{w}_i(\mathbf{f}_{c(8\times i)} - \mathbf{f}_{c(8\times i+1)}) \|^2]^{\frac{1}{2}} \tag{2}$$

where $\| \bullet \|$ is the l_2 norm and $\mathbf{W} = diag[\mathbf{w}_1\mathbf{w}_2\ldots\mathbf{w}_{N/8-1}]$ is a diagonal weighting matrix which takes into account the local spatial characteristics[13,16]. The weighting function used in [14] is given by

$$w_{i,j} = \begin{cases} ln(1 + \frac{\sqrt{\mu_{i,j}}}{1+\sigma_{i,j}}) & if \mu_{i,j} \leq 128 \\ ln(1 + \frac{\sqrt{255-\mu_{i,j}}}{1+\sigma_{i,j}}) & otherwise \end{cases} \tag{3}$$

at location (i,j), taking into account the effect of illuminance level on the visibility of the distortion [15]. It reflects the fact that the block-edge artifacts are masked off in extreme bright and dark as well as spatially busy areas in the image. The weighting function is shown in Figure 1, assuming $\sigma_{i,j} = 0$.

For horizontal boundaries, the local mean $\mu_{i,j}$ is determined from the mean of the pels within the two adjoining blocks of the current row, i.e.

$$\mu_{i,j} = \frac{1}{16}\sum_{x=j-7}^{j+8} f(i,x) \tag{4}$$

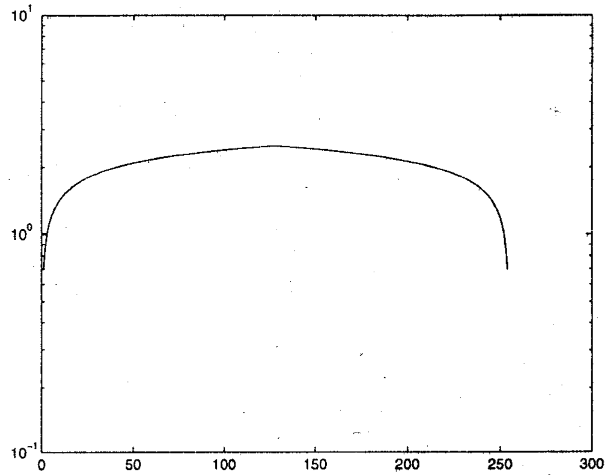

Figure 1: The weighting function.

where $f(i,x)$ are the pel values. Similarly, we define the standard deviation as follows:

$$\sigma i,j = [\frac{1}{16}\sum_{x=j-7}^{j+8}(f(i,x) - \mu_{i,j})^2]^{\frac{1}{2}} \tag{5}$$

We further normalize M_h by the average interpixel difference, E, between pels which are not at block boundaries, resulting in M_{hBIM}. The formula to calculate E is defined as:

$$E = \frac{1}{7}\sum_{k=1}^{7} S_k \tag{6}$$

where

$$S_k = [\sum_{i=1}^{N/8-1} \| \mathbf{w}_i(\mathbf{f}_{c(8\times i+k)} - \mathbf{f}_{c(8\times i+k+1)}) \|^2]^{\frac{1}{2}} \tag{7}$$

A metric M_{vBIM} can also be similarly defined to measure the vertical blockiness of the reconstructed video images. The blockiness metric used in [14] for the analysis of image reconstruction quality is given by $M_{BIM} = \alpha M_{hBIM} + \beta M_{vBIM}$.

The weighting function shown in Figure 1 gives highest weight to the distortions in areas where the average illuminance value is 128 on the scale of 0 to 255. In [15], Girod suggested that the distortions would be most noticeable where the illuminance value is between 70 and 90 (centred approximately on 81). To accommodate this observation and to maintain the simplicity of weighting function, Equation 3 is modified as follows:

$$w_{i,j} = \begin{cases} \lambda ln(1+\frac{\sqrt{\mu_{i,j}}}{1+\sigma_{i,j}}) & if \mu_{i,j} \leq \zeta \\ ln(1+\frac{\sqrt{255-\mu_{i,j}}}{1+\sigma_{i,j}}) & otherwise \end{cases} \tag{8}$$

where ζ is the selected average illuminance value where highest weight should be given to the distortion, and λ is calculated as in Equation 9:

$$\lambda = \frac{ln(1+\sqrt{255-\zeta})}{ln(1+\sqrt{\zeta})} \tag{9}$$

The weighting function defined in Equation 8 is shown in Figure 2, assuming $\sigma_{i,j} = 0$ and $\zeta = 81$.

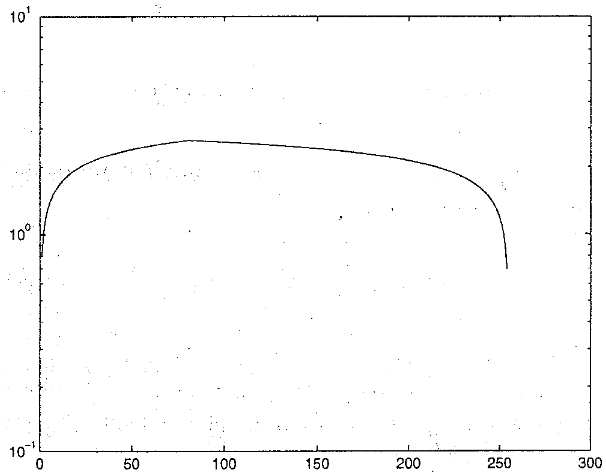

Figure 2: The modified weighting function.

This new generalized M_{BIM} is represented by M_{GBIM}.

3. SIMULATION RESULTS

In our experiments, we used CIF images (352×288) and assumed that the human sensitivity to horizontal and vertical blocking artifacts are similar[10], and therefore selected $\alpha = \beta = 0.5$. The values obtained using M_{GBIM} are found to be consistent with subjective evaluation.

A reconstructed I picture "Mobile and Calendar" (MPEG-1 coded at 0.8 Mbps) is shown with its M_{GBIM} value in Figure 3, compared with a POCS filtered reconstruction of the same picture, also with its M_{GBIM} value, in Figure 4. It is shown that the POCS filtering reduces the blocking artifacts significantly and M_{GBIM} is a very effective measure for

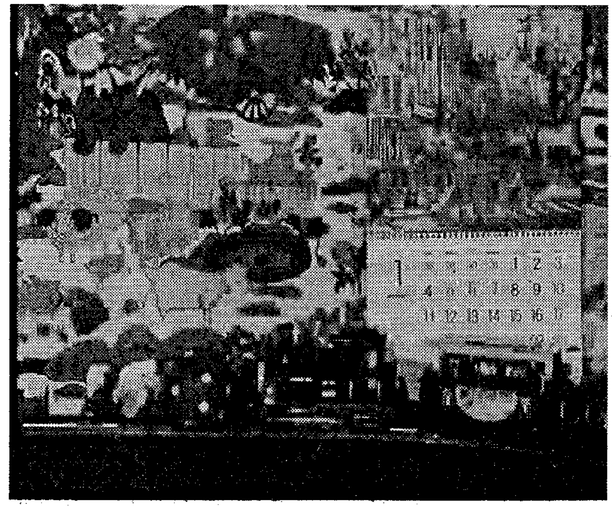

Figure 3: Reconstructed I Picture from MPEG-1 coded "Mobile and Calendar" video sequence (0.8 Mbps, IBBBPBBBP...). $M_{GBIM} = 3.08$ and $PSNR = 21.76dB$.

blocking artifacts. It is also interesting to note that the reconstructed picture has $M_{hGBIM} = 3.29$ and $M_{vGBIM} = 2.88$, respectively, (indicating that the horizontal blockiness or vertical edge artifacts are more prominent than the vertical blockiness or horizontal edge artifacts). The POCS filtered reconstruction of the same picture has $M_{hGBIM} = 1.08$ and $M_{vGBIM} = 1.08$, respectively.

The blocking artifacts metric M_{GBIM} was also used in the evaluation of several other MPEG-1 coded sequences at various coding bit rates, including "Flower Garden", "Football", "Table Tennis" etc., and showed satisfactory and consistent results.

4. CONCLUSIONS

This paper introduced a generalized block-edge impairment metric as a blocking artifacts measure to evaluate reconstructed picture quality in the absence of the original images. It has shown that the evaluation of blocking artifacts using this metric is very effective and consistent with subjective evaluation.

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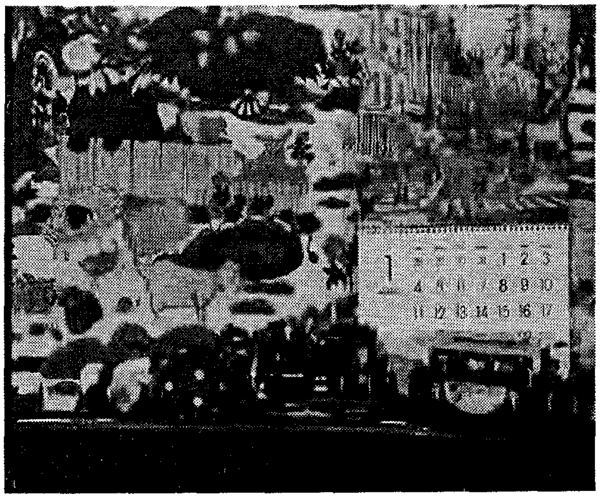

Figure 4: POCS filtered I Picture reconstruction from MPEG-1 coded "Mobile and Calendar" video sequence (0.8 Mbps, IBBBPBBBP...). $M_{GBIM} = 1.08$ and $PSNR = 21.88dB$.

References

[1] K. R. Rao and P. Yip, *Discrete Cosine Transform —Algorithms, Advantages, Applications.* Academic Press Inc., 1990.

[2] M. Yuen and H. R. Wu, "Reconstruction artifacts in digital video compression," in *Proceedings of the conference Digital Video Compression: Algorithms and Technologies 1995, part of IS&T/SPIE's Symposium on Electronic Imaging: Science & Technology*, vol. 2419, pp. 455–465, February 1995.

[3] R. L. Schmidt, A. Puri, and B. G. Haskell, "Performance evaluation of nonscalable mpeg-2 video coding," in *Proceedings of SPIE Visual Communications and Image Processing*, vol. 2308, pp. 296–310, September 1994.

[4] CCIR, "CCIR Rec. 500-5—Method for Subjective Assessment of the Quality of Television Pictures," in *1992-CCIR Recommendations, RBT Series*, pp. 166–189, September 1992.

[5] John O. Limb, "Distortion criteria for the human viewer," in *IEEE Transactions on System, Man, Cybernetics*, vol. 9, pp. 778–793, December 1979.

[6] S. A. Karunasekera and N. G. Kingsbury, "A distortion measure for blocking artifacts in images based on human visual sensitivity," in *Proc. SPIE Visual Commun. and Image Processing*, vol. 2094, (Cambridge, MA), pp. 474–486, Soc. Photo–optical Instrumentation Engineers, 1993.

[7] H. R. Wu, "Analysis of video reconstruction artifacts and quality metrics," in *Proceedings of Australian Telecommunication Networks & Applications Conference 1995*, pp. 191–194, December 1995.

[8] CCITT Study Group XV, "Draft revision of recommendation H.261–video codec for audiovisual services at p×64 kbit/s," tech. rep., CCITT, 1989.

[9] ISO/IEC 13818, "Information technology–generic coding of moving pictures and associated audio information," tech. rep., ISO/IEC, November 1994.

[10] Shanika A. Karunasekera and Nick G. Kingsbury, "A distortion measure for blocking artifacts in images based on human visual sensitivity," in *IEEE Transactions on Image Processing*, vol. 4, pp. 713–724, June 1995.

[11] Makoto Miyahara, "Quality assessments for visual service," in *IEEE Communications Magazine*, pp. 51–60, October 1988.

[12] W. Xu and G. Hauske, "Picture quality evaluation based on error segmentation," in *Proceedings of SPIE Visual Communications and Image Processing*, vol. 2308, pp. 1454–1465, September 1994.

[13] Y. Yang, N. P. Galatsanos, and A. K. Katsaggelos, "Projection-based spatially-adaptive reconstruction of block-transform compressed images," in *Proceedings of SPIE Visual Communications and Image Processing*, vol. 2308, pp. 1477–1488, September 1994.

[14] H. R. Wu and M. Yuen, "Quantitative quality metrics for video coding blocking artifacts," in *Proceedings of 1996 Picture Coding Symposium*, March 1996.

[15] B. Girod, "The information theoretical significance of spatial and temporal masking in video signals," in *Proceedings of SPIE Conference on Human Vision, Visual Processing and Digital Display*, vol. 1077, pp. 178–187, Soc. Photo–optical Instrumentation Engineers, 1989.

[16] M. Yuen, H. R. Wu, and K. R. Rao, "Performance evaluation of pocs loop filtering in generic MC/DPCM/DCT video coding," in *Proceedings of the SPIE International Conference on Visual Communications and Image Processing'95*, vol. 2501, pp. 65–75, May 1995.